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On the Locus of Contextual Interference in Motor Skill Acquisition.

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ON THE LOCUS OF CONTEXTUAL INTERFERENCE IN MOTOR SKILL ACQUISITION

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FORWARD

This dissertation has been written in the style adopted by the American Psychological Association for submission to scholarly journals. Pages 1-53 represent the body of the manuscript as prepared for journal submission. The remaining pages constitute the appendix, and consist of some background issues on contextual interference, an illustration of the apparatus, and tables of MANOVAs, ANOVAs, and means.

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ABSTRACT

Three experiments are reported which investigate the role of contextual variety effects in motor skill acquisition. In Experiment 1, results revealed that despite previous methodological confoundings of contextual variety with response paradigm manipulations the critical retention advantage of random over blocked practice schedules was maintained. In Experiment 2 the inclusion of a group which combined attributes from random and blocked practice schedules produced evidence which implicated the role of event repetitions as the experimental variable from which contextual variety effects arise. By changing the task goals in Experiment 3 to emphasize the processing of error information as the cognitive activity most critical to performance, support for a problem-solving approach to event repetition effects was found. These findings were discussed in a theoretical framework which incorporates recently revamped notions of the role of cognition in motor skill acquisition.

GENERAL INTRODUCTION

A considerable amount of research activity has recently emerged regarding the general issue of how intentions for action evolve into motor performance. For highly practiced tasks, a common view is that there is an automated translation from intention to movement (e.g., Schneider & Fisk, in press; Stelmach & Larish, 1980). However, for tasks which are not well learned, the implication is that conscious mechanisms subserve this translation process (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

In a similar vein, the process of skill acquisition seems to be the product of an interaction between cognition and motor control. While the latter stages of skill acquisition seem to involve the refinement of movement coordination, the initial phase is heavily influenced by changes in the cognitive aspects of performance (Adams, 1971; Fitts, 1964). One remarkable demonstration of this interaction between cognition and skill acquisition has been termed the contextual interference effect. For unpracticed tasks, interfering with the cognitive events which subserve the intention to action translation process may be accomplished by simply structuring the acquisition trials in a highly unpredictable (random) manner. While the resultant decrement to performance is understandable, this interference produces a surprising, yet consistent facilitation to retention, relative to low interference practice conditions (see Shea & Zimny, in press, for a review).

Originally identified as a curious paradox in the verbal learning literature (Battig, 1966, 1972, 1979), "contextual interference" may be manifested: a) when there is an increase in the similarity among items to be learned, or b) when there is an increase in the variety of processing requirements on successive trials. This latter aspect of interference, contextual variety, was the focus of the first experiment demonstrating this paradox in the acquisition of motor skills (Shea & Morgan, 1979). They found that the retention for three movement patterns was a function of the practice conditions under which acquisition trials were performed: superior retention occuring under acquisition trials where all three movement patterns were practiced randomly as opposed to a blocked condition where all practice trials for one pattern were completed before practice on another pattern was undertaken. Keeping the number of total trials on each pattern the same across conditions, Shea and Morgan demonstrated that the contextual variety conditions alone were sufficient to produce considerable retention effects. Indeed, a number of studies conducted in Shea's lab and elsewhere (summarized by Shea &

Zimny, in press) have shown this advantage of random over blocked contextual variety conditions to be a very robust phenomenon.

Consonant with the skill acquisition theories of Fitts (1964) and Adams (1971), Shea has attributed the contextual variety effect in motor learning primarily to the cognitive processing requirements needed to perform the task. Moreover, the advantage of random over blocked practice conditions has been attributed to enhanced distinctive and elaborative processing of the cognitive components involved in the task (Battig & Shea, 1980; Shea & Morgan, 1979; Shea & Zimny, in press). However, while this theoretical interpretation may hold heuristic appeal (e.g., Schmidt, 1982), none of the studies conducted since the Shea and Morgan experiment have empirically addressed the issue of what, specifically, is the locus of the contextual interference effect. Indeed, this question actually involves two important issues. First, what are the methodological differences between the manner by which the random and blocked practice trials are structured that produce these acquisition and retention effects? Second, and more important, how are the cognitive processes involved in skill acquisition differentially affected by this methodological "locus" of contextual variety? The present experiments were designed to address these empirical issues.

Experiment 1

In the Shea and Morgan experiment[1] the subjects' task was to respond to a particular stimulus light as quickly as possible by knocking down a series of hinged barriers in an order which was specific to the color of the signal to respond. Under random acquisition conditions, any of three possible signals to respond could be illuminated, making the task a choice response paradigm. However, under blocked conditions, only one signal and one diagram illustrating the appropriate response were present during the practice trials for that movement pattern, reducing this condition to a simple response paradigm. Thus, due to the confounding of practice schedule effects (i.e., random vs. blocked practice schedules) with response paradigm effects (i.e., choice vs. simple responses), it is impossible to determine whether the locus of the contextual variety effects arises from the manipulation of practice schedules, response paradigms, or an interaction of each.

In the present experiment the procedures employed by Shea and Morgan were altered such that the simple effects of contextual variety and response paradigm might be assessed. In addition to a replication of Shea and Morgan's interference groups (denoted here as the cued-blocked and uncued-random groups) two new groups were tested (designated as uncued-blocked and cued-random). Here, the "cueing" factor (cued vs. uncued) referred to whether or not a warning light provided information as to nature of the upcoming signal to respond. The contextual variety factor (blocked vs. random) referred to the sequential nature of presenting the different signal-pattern trials. Together, these groups provide the necessary controls to permit an assessment of contextual variety and response paradigm effects on contextual interference. Under these arrangements, the following comparisons were of particular interest: a) cued-blocked vs. uncued-random (to attempt to replicate Shea & Morgan's findings), b) cued-random vs. uncued-random (to assess the relative contribution of response paradigm holding contextual variety constant), and c) cued-blocked vs. cued-random (to assess the relative contribution of contextual variety holding response paradigm constant)[2].

Method

Subjects

Twenty-four right-handed undergraduates (12 males and 12 females; mean age=22.9 yrs) from psychology and physical education classes at Louisiana State University participated in the experiment for course credit. All subjects were naive as to the purposes of the study.

<u>Apparatus</u>

The task used was similar to that used by and depicted in Shea and Morgan (1979, their Figure 1). In general, the task consisted of two sets of light signals mounted on the rear panel of the apparatus (which comprised the "stimuli"), a pushbutton microswitch, six hinged wooden barriers, and a telegraph key mounted on the base of the apparatus (which comprised the "response").

The warning signal consisted of a 1.6 cm hole cut in the rear panel and covered by a small sheet of white tracing paper (to project the light). Behind the hole, on the back side of the rear panel was attached a small plastic box lined with aluminum foil that housed four colored lights (red, green, blue, and white). The three lights which served as the signals to respond were located 13 cm below the warning light and 20 cm apart (blue directly below the warning light with the green and red to the left and right, respectively). All lights were base-threaded, incandescent bulb units that were fitted with removable colored lens caps. Experimenter control over the choice of colored lights for a particular trial as well as the time period between the warning light and the signal to respond (i.e, the foreperiod) was afforded by a non-commercial unit located behind the rear panel and out of the subject's view. RT and MT were measured using two Lafayette millisecond timers (Model # 54035), also located behind the rear panel of the apparatus.

The barriers were 8.9 x 12.1 cm wooden blocks that were attached to the wooden base by metal hinges (arranged to fall outward). All of the blocks were foam-padded. The base of the task was arranged such that the pushbutton microswitch and the telegraph key were centered at the front and rear of the base, respectively, 47.8 cm apart. The six barriers were arranged from front to rear in three pairs (one left and one right of center), each pair 20 cm from the midline of the base and 10 cm from the next pair (i.e., on each side the barriers were 10 cm apart, from front to rear). The first pair was located 10 cm to the rear of the start microswitch. The last pair was parallel with the telegraph key.

Illustrations for each movement pattern were drawn on 6 x 12 cm manilla tags and hung on small metal hooks attached to the rear panel directly below its paired colored light. The rear panel was attached perpendicular to the base of the apparatus.

Procedures

Upon arriving at the lab, the subject read and signed the consent form and was lead into the testing room. There, the procedures for the first two phases of the experiment were explained. In total, the experiment consisted of the following four phases: a) the preliminary phase, b) the acquisition phase, c) the interpolated phase, and d) the retention phase.

Preliminary Phase. During the preliminary phase the subject was given instructions regarding the nature of the task as well as three practice trials. The instructions informed the subject that on each trial two lights would be illuminated, a warning light and a signal to respond, and that a 2-5 sec variable foreperiod would separate these lights. Subjects in the cued groups were told that both lights would be of identical color whereas subjects in the uncued groups were told that the warning light would always be white. Their task was to depress the pushbutton start microswitch when the warning light occurred and, upon illumination of the signal to respond, knock over the wooden barriers and depress the telegraph key in the prescribed order.

Following these instructions the experimenter replaced the middle (blue) lens cap with a white lens cap and hung a manilla card illustrating a practice pattern (used only for these practice trials). Prior to the three practice trials the experimenter demonstrated the task, emphacizing that the response should be made as rapidly as possible. Following this, the subject performed three (errorless) practice trials.

Acquisition Phase. After the practice trials the illustration was removed, the lens cap replaced, and the three acquisition patterns were hung below their associated signal to respond. Subjects were then given 1 min to familiarize themselves with the patterns, but not to practice knocking down the barriers. All subjects were told that the acquisition phase consisted of 54 trials, with 18 trials on each signal-pattern pair. The only difference in instructions given to each group was with respect to how the practice schedule would be arranged (i.e., trials occurred in a blocked or random sequence). Subjects were further informed that movement time (MT) feedback would be provided after each trial, and that they should try to improve their time throughout the entire acquisition phase. After any questions had been answered the acquisition phase was begun.

For the blocked groups all 18 trials on a particular pattern were performed consecutively. The six permutations of testing order (red-blue-green; blue-red-green; etc.) were distributed across subjects. For the random groups, the order of presentation was constrained only such that in each of the 6 sets of 9 trials the 3 signal-pattern pairs occurred 3 times, but no same pattern more than twice in succession. When an error occurred (one trial out of 20 on the average), the trial was repeated (immediately for the blocked groups and at the end of that set of trials for the random groups). The warning light and signal to respond were illuminated for approximately 300 msec each. Immediately following each trial, knowledge of results (KR) regarding the speed of the movement (to the nearest msec) was given verbally as the subjects restood the knocked-down barriers. The interval between MT feedback and the next warning signal was approximately 8 sec.

Interpolated Phase. During this phase the subjects were lead into a small room adjoining the testing room and performed a variation of the Stroop task (Stroop, 1935). This task required subjects to read letters from two sheets of paper by speaking the colors which the letters were printed in as rapidly as possible. On the first page the letters formed rows of X's. On the second page were color names which were printed in incompatible ink colors (e.g., the word 'green' printed in red ink would require the subject to respond "red"). The Stroop task task was deemed appropriate to prevent mental rehearsal of the movement patterns due to its cognitive demand. Further, to the degree that speech responses to color-driven perceptual events might be similar to the learned task, this task also provided a source of structural interference. The time to perform the Stroop task was approximately 4 min.

Retention Phase. Following the interpolated activity, the subject was returned to the testing room. With the illustrations removed the retention procedures were explained to the subject. The retention phase consisted of three trials of each signal-pattern pair, arranged such that a pair was never repeated immediately (i.e., randomly). Further, the warning signal was white (i.e., a choice response required) and KR was not provided. Before testing began, the experimenter emphasized that while responses were to be made as fast as possible, errors should be kept to a minimum. If a subject could not remember a particular movement pattern the experimenter demonstrated the appropriate response by pointing to the sequence of barriers to be knocked down. Following the retention phase the subject was briefed as to the entire nature of the research and thanked for participating.

Analytical Procedures

For each pattern the 18 acquisition trials were arranged into 6 sets of 3 trials (identical to the procedure adopted by Shea & Morgan). One set of three trials for each of the particular signal-pattern pairs comprised the retention data.

Separate statistical analyses were conducted to assess acquisition and retention performance. For each analysis, a MANOVA was initially performed with both reaction time (RT) and MT as dependent measures. Following the MANOVA separate ANOVAs on each dependent measure were performed, with only the significant effects from the MANOVA tested. Post-hoc comparisons of means were performed on significant ANOVA effects using the Newman-Keuls procedure. In addition to these analyses, adjusted variances accounted for by the significant effects from the ANOVA (ω^2) were calculated

(Tolson, 1980). The level for statistical significance was set at α=.05. However, ω^2 will be used to place into perspective those significant effects whose variance accounted for is quite small (< 2%).

Results and Discussion

A summary of the group means for acquisition performance and retention are illustrated in Figures 1 and 2 (for RT and MT, respectively).

Insert Figures 1 and 2 about here

Acquisition Phase

The analyses (MANOVA and ANOVAs) involved 2 (cueing) x 2 (contextual variety) x 6 (trial blocks) x 3 (movement pattern) models with repeated meaures on the last two factors. For the separate groups factors the MANOVA revealed significant main effects for cueing, Wilk's Exact F (2,19) = 18.27, contextual variety, F (2,19) = 11.45, and a significant interaction, F (2,19) = 6.61. A follow-up univariate ANOVA for RT also showed these significant effects: cueing, F (1, 20) = 30.64, ω^2 = 23.5%; contextual variety, F (1, 20) = 22.34, ω^2 = 16.9%; and their interaction, F (1, 20) = 13.92, ω^2 = 11.8%. Post-hoc analyses on the interaction revealed that the RT for the uncued-random group was significantly longer than the other three groups, which were themselves not significantly different. The univariate ANOVA for MT however, revealed only a cueing effect, $\underline{F}$ (1, 20) = 10.52, ω^2 = 11.2%, indicating that the cued groups performed significantly faster, on the whole, than did the uncued groups.

The MANOVA also revealed a significant trial blocks effect, $\underline{F}$ (10, 198) = 37.21, as well as second order interactions of block with cueing, $\underline{F}$ (10, 198) = 7.45, and contextual variety, $\underline{F}$ (10, 198) = 5.21. The univariate ANOVAs for RT and MT both mirrored the block main effect, $\underline{F}$ (5, 100) = 27.97, ω^2 = 9.6% and $\underline{F}$ (5, 100) = 117.14, ω^2 = 28.7% for RT and MT respectively. Of the second order interactions with blocks only the cueing by blocks interaction was significant for RT, $\underline{F}$ (5, 100) = 4.69, ω^2 = 1.3%. As may be seen in Figure 1, the first block of trials for the uncued-blocked group, (the first trial of which was a choice response) seemed to have contributed most to this interaction. Indeed, the small variance accounted for reflects this lack of a powerful interaction. For MT, blocks interacted with cueing, $\underline{F}$ (5, 100) = 12.95, ω^2 = 2.9% and with contextual variety, $\underline{F}$ (5, 100) = 10.91, ω^2 = 2.4%. As may be seen in Figure 2, the general trend is for a more rapid asymptoting of the cued groups and for the blocked groups (substantiated by the post-hoc tests).

These data support and clarify the nature of contextual variety effects during the acquisition phase reported by Shea and Morgan (1979). Considering their original groups (here denoted as cued-blocked and uncued-random), the present findings clearly replicate the performance differences. However, as apparent in Figure 1, the major impact upon RT performance was the effect of response paradigm. As expected, choice responses (uncued-random) were produced much slower than simple responses. Under cued conditions though, there was no effect of blocked vs. random practice schedules during acquisition. For MT a different pattern emerges. The interaction of response paradigm over trial blocks supports Kerr's (1978) contention that choice response conditions produce influences which have an impact on both RT and MT. More importantly, the contextual variety effects for MT are consonant with the findings reported by Shea and Morgan. That is, random practice produces effects on MT which are eventually overcome with practice (relative to blocked conditions).

The MANOVA revealed two further significant effects, due to the specific movement pattern performed, $\underline{F}$ (4, 78) = 7.76, and a blocks by pattern interaction, $\underline{F}$ (20, 398) = 1.97. Follow-up tests revealed only the MT main effect for pattern to be of consequence, $\underline{F}$ (2, 40) = 18.09, ω^2 = 4.1%. Post-hoc analysis revealed that the "red" movement pattern was performed faster ($\underline{M}$ = 752 msec) than the "green" ($\underline{M}$ =

806) and "blue" patterns ($\underline{M}$ = 863), which were themselves not different. Significant ANOVA effects were found for the RT movement pattern effect, $\underline{F}$ (2, 40) = 5.56, ω^2 = 0.6%, and for the MT blocks by pattern interaction, $\underline{F}$ (10, 200) = 2.65, ω^2 = 0.6%, but since the variance accounted for was so small in these cases post-hoc tests might be hazardous.

Retention Phase

In the retention phase data from the last block of acquisition trials and the block of retention trials were used resulting in 2 (cueing) x 2 (contextual variety) x 2 (trial blocks) x 3 (movement pattern) models, with repeated measures on the last factor. The MANOVA revealed significant effects for trial blocks, $\underline{F}$ (2, 19) = 26.72, as well as cueing by blocks and contextual variety by blocks interactions, $\underline{F}$ (2, 19) = 5.29 and $\underline{F}$ (2, 19) = 8.83, respectively. Follow-up ANOVAs on the blocks effect was significant for RT, $\underline{F}$ (1, 20) = 47.22, ω^2 = 27.0%, and for MT, $\underline{F}$ (1, 20) = 38.36, ω^2 = 17.3%. ANOVAs on the cueing by blocks effect was significant for RT, $\underline{F}$ (1, 20) = 10.96, ω^2 = 5.8%, and small but significant for MT as well, $\underline{F}$ (1,20) = 4.46, ω^2 = 1.6%. Post-ANOVA tests on RT revealed that while the choice response conditions were significantly slower than the simple conditions on the last block of acquisition trials, no differences were found between groups during the choice condition retention test.

Further, the contextual variety by blocks interaction was also significant for both RT, $\underline{F}$ (1, 20) = 16.09, ω^2 = 8.8% and MT, $\underline{F}$ (1, 20) = 12.02, ω^2 = 5.1%. For RT, while random groups (most importantly, the uncued-random) were slower than blocked groups on trial block 6, the reverse occurred during retention. Under identical conditions, the random group performed significantly faster than the blocked group. For MT, a similar trend occurred, only that blocked and random groups had not been different at trial block 6.

These retention data also support and clarify the findings of Shea and Morgan. The influence of response paradigm upon RT, while critical to the interpretation of contextual variety effects during acquisition, seems to have much less of an impact upon retention. Rather, the major retention effects (for RT and MT) were due to the contextual variety factor. Similar to the Shea and Morgan findings, random practice schedules promoted better retention performance than blocked practice schedules.

The MANOVA further revealed an effect of movement pattern, $\underline{F}$ (4, 78) = 10.85 and a block by movement pattern interaction, $\underline{F}$ (4, 78) = 6.23. Follow-up ANOVAs on the movement pattern effect were significant for both RT, $\underline{F}$ (2, 40) = 16.51, ω^2 = 3.7% and MT $\underline{F}$ (2, 40) = 12.79, ω^2 = 5.6%. ANOVAs on the interaction also were significant for both RT, $\underline{F}$ (2, 40) = 9.59, ω^2 = 2.8% and MT $\underline{F}$ (2, 40) = 4.19, ω^2 = 1.3%. Post-hoc analyses revealed that (for RT and with caution, also for MT) while all movement patterns were performed equivalently fast on the last block of acquisition trials, the "red" pattern was performed significanty faster than the other patterns during the retention trials.

Finally, the MANOVA also revealed significant interactions of contextual variety with movement pattern and a triple interaction of contextual variety, blocks and movement pattern. However, since all variances accounted for by the follow-up ANOVAS were small (all < 1.1%), these interactions will not be statistically elaborated.

The pattern of RT and MT effects during retention performance provides an interesting insight into the decision processes affected by the experimental varables. Learning under choice response conditions resulted in essentially a zero correlation during choice response retention trials (uncued-random $\underline{r}$ = .15). However, learning under simple response conditions resulted in much higher RT-MT correlations when transfered to choice conditions (mean $\underline{r}$ = .58 for the other three groups). This finding suggests that the confounding of response paradigm in the Shea and Morgan experiment may have produced different action strategies. Inspection of Figures 1 and 2 reveals that for each of the three simple response conditions, both RT and MT increased markedly during retention. Together with the correlation data these findings suggest that there was a tendency to make response decisions prior to as well as during movement execution in these groups.

Comparing the contextual variety (controlled for response paradigm) effects however, reveals that similar influences upon RT and MT were exerted (cued-blocked r = .71 and cued-random r = .58). Given this similarity, the observed retention difference between these groups (as may be seen in Figures 1 and 2) auger well with Shea and Morgan's conclusions. In other words, the decisions which were made prior to response initiation as well as during movement execution were made faster for the random group than for the blocked group.

In summary, the findings for Experiment 1 suggest that contextual variety effects in motor skill acquisition as demonstrated by Shea and Morgan are due to different factors at different phases. The elevated RTs found for the random group were likely due to the response paradigm employed while MT differences were affected by both response paradigm and contextual variety effects. The retention data though, clearly support Shea and Morgan's contention that random contextual variety conditions facilitate remembering motor skills relative to blocked contextual variety conditions.

Thus, these findings suggest that the methodological locus of contextual variety effects arises from the manipulation of practice schedules, and is not due to the effects of response paradigm or the interaction of practice schedule with response paradigm. An argument against such an interpretation though, could be made based upon the similarity of transfer between random acquisition conditions and the nature of retention conditions (i.e., randomly-ordered). Indeed, that specificity of transfer from learning to retention conditions was found in this experiment supports previous research on the notion of contextual dependency (Lee & Magill, Note 1). However, under further investigation, this explanation is clearly inadequate towards an understanding of processes underlying contextual interference effects. In their study, Shea and Morgan (1979) also used retention trials that were performed under blocked contextual variety conditions. According to a specificity of acquisition-test view (Lee & Magill, Note 1), the blocked acquisition group should have performed better under blocked retention conditions than the random acquisition group. Instead, their data showed no differences between these two groups during blocked retention trials. Further, Del Rey (Note 2) has found that random acquisition conditions may actually result in *better* performance under blocked retention trials than blocked acquisition groups. Obviously, the findings point to the practice schedule manipulation as the locus of the contextual variety effect. Experiments 2 and 3 are designed in an attempt to uncover this locus.

Experiment 2

A focus upon the practice schedule differences between blocked and random conditions places an emphasis upon the effects of repetition/non-repetition of events: practice for a particular movement pattern under blocked conditions involves a repetition of the same muscular groupings and cognitive processes on repeated trials whereas this is only rarely the case for the random group (a chance occurrence) and even then, involving only one repetition. Indeed, event repetitions has been the source of considerable research activity for cognitive skills. In brief, the research findings suggest that spacing of repetitions of a word during the list versus repeating all instances of the word successively during list presentation (sometimes denoted as distributed vs. massed presentations) results in a retention advantage for the former group (Hintzman, 1974). Indeed, this phenomenon for word recall has been likened to the process of solving a mathematical problem or some other cognitive event (Jacoby, 1978). That is, after solving the problem, immediate presentation of the same problem allows the correct solution to be remembered without the necessity of having to go through the operations involved in re-solving the problem. Under spaced presentations however (i.e., the repetition effect), the answer to the solution is not available and hence the problem-solving process is again undertaken. Jacoby has suggested that retention performance is poorer for immediately re-presented problems because "the solution is remembered rather then being constructed" (p.666).

Jacoby's arguments are strikingly reminiscent of arguments offered on motor skill acquisition many years ago by the Russian scientist Bernstein (English translation, Bernstein, 1967):

> The processes of practice towards the achievement of new motor habits essentially consists in the gradual success of a search for optimal motor solutions to the appropriate problems. Because of this, practice, when properly undertaken, does not consist in repeating the <u>means of solution</u> of a motor problem time after time, but in the <u>process of solving</u> this problem again and again by techniques which we changed and perfected from repetition to repetition (p. 134).

The implications of the above arguments towards the locus of contextual variety effects attributes the repetition/non-repetition of movement patterns to cognitive processes involved in learning the goals of the task. That is, the planning decisions regarding an upcoming movement must be "constructed" rather than just "remembered" from the action plans for the previous trial under random practice conditions. Further, a facilitation of retention is consonant with the robust phenomenon that constructing action plans leads to superior memorial performance relative to when action plans do not have to be formed for movement (viz. the preselection effect -- Kelso & Wallace, 1978; Lee & Gallagher, 1981).

Another possibility, arising from the repetition/non-repetition of events, could be due to the predictability of upcoming events. Previous research has shown that when a highly predictable, non-repetitive event occurs the problem-solving process may by circumvented. This "alternation effect" (Keele, 1973; Kirby, 1980) would also suggest then that random practice involves greater cognitive effort (resulting in improved retention) due to the unpredictable nature of the presentation of events.

In the present experiment the above two hypotheses are compared by the addition of a third contextual variety condition which combines a feature of the random condition (non-repetition of events) with a feature of the blocked group (perfect predictability of events). Under this practice schedule, subjects are presented trials in blocked orders of triplets (i.e., the 54 trials are blocked into 18 presentations of a particular testing order -- e.g., red-blue-green). According to the above arguments, this "serial" condition should produce delayed retention results similar to the random condition if non-repetition of events produces the contextual variety effect. Alternatively, if contextual variety effects are due to the unpredictability of upcoming events, then delayed retention results for this serial group should, like the blocked condition, be poorer than under random practice schedules.

Method

Subjects

Thirty undergraduates (21 females and 9 males; mean age = 19.8 yrs) from psychology and physical education classes at Louisiana State University participated in the experiment for course credit. None of the volunteers had served as subjects in Experiment 1.

Apparatus

The apparatus and materials were identical to those used in Experiment 1. To combat possible effects of intratask similarity[3], the illustration used for the red light was switched to the blue. The blue pattern was changed slightly (the last barrier knocked over was the right-rear instead of the left rear) and moved to be paired with the red signal to respond.

Procedures

All task-related and analytical procedures were identical to those used for the cued-random and cued-blocked groups in Experiment 1, wih three exceptions. First, an additonal, "serial", group was tested. Subjects in this group received the 54 acquistion trials in 18 triplets of 3 identical testing sequences (order balanced across subjects). Second, instructions to the subject provided information as to the exact nature of the retention test and prompted that he/she should learn to remember which pattern was paired with each light in addition to learning to move as quickly as poosible. This change in procedures was also used to help eliminate possible confounding effects of intratask similarity (see Footnote 3 and Shea, in press). Third, following the Stroop test during the interpolated phase, subjects were presented a written recall test. On the test sheet were three illustrations of the task, similar to those used to illustrate the movement patterns, but without the lines illustrating the direction of movement. Above each illustration was the name of a color. The subject's task was simply to draw the pattern of movement execution associated with each of the signal colors. This recall test was performed, usually, in less than a minute.

Results and Discussion

Acquisition Phase

Insert Figures 3 and 4 about here

The analyses (MANOVA and ANOVAs) involved 3 (groups) x 6 (trial blocks) x 3 (movement pattern) models with repeated measures on the last two factors. The MANOVA revealed significant main effects for blocks, $\underline{F}$ (10, 268) = 36.54, and a significant groups by block interaction, $\underline{F}$ (20, 268) = 2.86. Follow-up ANOVAs revealed that the blocks effect was significant for both RT, $\underline{F}$ (5, 135) = 37.41, ω^2 = 20.8% and MT, $\underline{F}$ (5, 135) = 105.49, ω^2 = 23.0%. Newman-Keuls test revealed that while RT asymptoted by the second block of trials, MT did not asymptote until Block 4 (see Figures 3 and 4). The ANOVA also revealed that the group by block interaction was only significant for MT. As may be seen in Figure 4, post-hoc analyses revealed a significant difference between the blocked group and the other two groups at trial blocks 1-3.

These findings are consistent with the results from Experiment 1 for both RT and MT. However, the more interesting finding is the virtual overlapping of group means for the random and serial groups as may be seen in Figures 3 and 4. Thus, from the acquisition data, it appears that factors producing contextual variety effects under random practice schedules may also be affecting the serial group as well (at least for acquisition performance).

The MANOVA also revealed one further significant effect for movement pattern, $\underline{F}$ (4, 106) = 14.77. Follow-up analyses showed this effect to be significant only for MT, $\underline{F}$ (2, 54) = 28.57, ω^2 = 3.2%, and that the red movement pattern was performed more slowly than the other two patterns.

Written Recall

A one-way ANOVA was performed on the number of correctly remembered barriers associated with each signal-pattern pair (total possible correct = 9). Although the mean percent recalls appear different (blocked $\underline{M}$ = 67.8%, random $\underline{M}$ = 82.2%, serial $\underline{M}$ = 92.2%), the ANOVA just failed to reach staistical significance, $\underline{F}$ (2, 27) = 2.57, ω^2 = 9.5%, .10 < $\underline{p}$ < .05.

Retention Phase

The MANOVA revealed significant effects for blocks, $\underline{F}$ (2, 26) = 139.13, a group by block interaction, $\underline{F}$ (4, 52) = 6.99, and a main effect for movement pattern, $\underline{F}$ (4, 106) = 7.63. Follow-up ANOVAs revealed significant block effects for both RT $\underline{F}$ (1, 27) = 169.05, ω^2 = 61.2% and MT, $\underline{F}$ (1, 27) = 141.53, ω^2 = 24.6%. The difference between responding on the last block of acquisition trials versus the retention trials reflects the change, for all groups, from a simple to a choice response paradigm. The groups by blocks interaction, as illustrated in Figures 3 and 4, was also significant for both RT, $\underline{F}$ (2, 27) = 4.28, ω^2 = 2.4% and MT, $\underline{F}$ (2, 27) = 15.16, ω^2 = 5.0%. Post-hoc analyses for both RT and MT indicated the same results: while all groups performed similarly in the last block of acquisition trials, the blocked group was significantly slower on the retention trials than the random and serial groups, which were themselves not different.

The significant MANOVA effect for movement pattern was only found to be significant in the MT ANOVA, F (2, 54) = 16.49, ω^2 = 4.0%. Post-hoc tests revealed that the blue pattern (which was the red pattern in Experiment 1) was still performed faster (M = 768) than either the green (M = 810) or the red (M = 877) patterns. Further, the green pattern was also performed faster than the red pattern. However, the interaction of movement pattern with contextual variety conditions observed in Experiment 1 was not revealed here. Thus, the possible confounding of contextual variety effects with interresponse similarity effects was eliminated.

Again, these data also replicate and extend the findings from Experiment 1. While the random-blocked difference was found again, the critical finding here was the continued identical pattern of results for the serial and random conditions (see Figures 3 and 4). Given that the primary methodological similarity between random and serial practice schedules is the order in which events are practiced, it seems apparent that the methodological locus of the contextual variety effect lies in the non-repetitive nature of the practice schedules.

Given this conclusion though, the question remains as to what specific cognitive involvements in the motor learning process are being affected by the manipulations of practice schedules. According to the views presented earlier regarding (verbal) event repetitions (Jacoby, 1978) and motor repetitions (Bernstein, 1967), it may be argued that contextual variety effects are due to the differences in problem-solving activities which arise as a consequence of the practice schedule manipulations. Considering the goals of the task in Experiments 1 and 2, the prime suspects for cognitive involvement are the decisions regarding where to move to knock over the next barrier. Under event repetition conditions (i.e., blocked practice schedules), these decisions are easily remembered from trial to trial, involving less problem-solving activities for solution of the task, and consequently leading to poor retention performance. Under non-repetitive event conditions (i.e., random and serial practice schedules), intervening movement patterns between repetitions of the same motor problem necessitate that the action commands on each trial be re-solved, resulting in a facilitation of retention. While these speculations fit the results of the present experiments quite nicely, further support for this emphasis upon the problem-solving aspects of the task would occur if contextual variety effects could also be manifested under different task goals (i.e., under similar cognitive processing requirements as in Experiments 1 and 2, but under different strategic requirements).

Experiment 3

A common view of skill acquisition emphasizes error feedback (or KR) as the primary source of information used to solve motor problems (e.g., Adams, 1971). If a problem-solving approach to the questions regarding the locus of contextual variety effects is appropriate, a change of task goals such that the processing of error information becomes the prime component of cognitive activity during skill acquisition should produce similar differences between practice schedule conditions as found in Experiment 2. Failure to find similar results would argue against this problem-solving approach to contextual variety effects.

In the present experiment the goals of the task were not to perform the movement patterns as rapidly as possible, but rather to perform each pattern to a specific criterion time. Thus, the critical problem-solving activity involves processing the error information from previous attempts in order to produce timing commands which more accurately approximate the criterion movement time.

Method

Subjects

Thirty female undergraduates (mean age = 21.9 yrs) from psychology and physical education classes at Louisiana State University participated in the present experiment for course credit. None of the volunteers had participated in Experiments 1 or 2.

Apparatus

The apparatus and all materials were the same as those used for Experiment 2. The only modifications involved covering the warning signal light and using only one of the millisecond timers.

Procedures

In the present experiment all manipulations with respect to the ordering of trials in the three groups were consonant with Experiment 2. The major difference in the present experiment was the goals of the task.

Here, no warning light was provided because the signal to respond merely indicated which pattern was to be performed. Subjects were prompted to begin their performance for a particular pattern by depressing the start microswitch after the associated light was illuminated. Holding the start button down, subjects were encouraged to begin their movement only when they were ready. Directly above the illustrations associated with each colored light were tags indicating the criterion time for each pattern (blue = 900 msec; green = 1050; red = 1200). Subjects were informed that a millisecond timer began after leaving the start button and terminated upon depression of the telegraph key. Further, it was explained that the goals of the task were to learn to perform each pattern as close to the associated criterion time as possible. The experimenter also explained that KR, given as the MT immediately after the trial, could be used as a basis for speeding up or slowing down future attempts on that pattern.

Following the acquisition phase subjects again performed the interpolated task, but not the written recall test (used in Experiment 2). In order to deemphasize the importance of decisions regarding where to move as the primary cognitive learning component, the movement pattern illustrations were available for viewing during retentionn trials. Further, the number of randomly-ordered, no-KR retention trials was doubled (to 18) in order to assess the impact of the information withdrawal over a longer period of time.

Analytical Procedures

Performance scores on each trial were transformed into signed error scores (i.e., error = MT - criterion time). Using the trial blocks procedures from Experiments 1 and 2, three error measures were calculated. Total error (E) was considered the overall measure of acquisition and retention performance, whereas the more descriptive measures, absolute constant error (|CE|) and variable error (VE), were considered indices of performance accuracy and consistency, respectively. Due to problems of multicollinearity (Thomas, 1977), only |CE| and VE were included in the initial MANOVA. A separate ANOVA was performed on the E data.

Results and Discussion

Insert Figure 5 about here

Acquisition Phase

The analyses involved 3 (groups) X 6 (trial blocks) X 3 (movement patterns) models with repeated measures on the last two factors. The ANOVA for E revealed significant main effects for groups, F (2, 27) = 6.55, ω^2 = 3.8% and for trial blocks, F (5, 135) = 20.81, ω^2 = 14.9%. The MANOVA on |CE| and VE also revealed main effects for groups, F (4, 52) = 5.21 and for blocks, F (10, 268) = 8.62. Follow-up ANOVAs were significant for the group effect only for |CE|, F (2, 27) = 12.56, ω^2 = 4.3%. However, the ANOVAs revealed significant differences over trial blocks for both |CE|, F (5, 135) = 14.10, ω^2 = 10.3% and VE, F (5, 135) = 11.19. ω^2 = 8.1%. Post-hoc tests on the differences between groups revealed the same results for E and |CE|: subjects in random and serial groups performed less accurately during the acquisition phase than did subjects in the blocked group. For the trial blocks effect, the analyses revealed the while performance in general (E) and performance accuracy (|CE|) asymptoted by block 3, consistency of responding (VE) asymptoted by block 2. These data show trends similar to the findings of Experiment 2 in that the random and serial groups performed with equivalent accuracy yet poorer than the blocked group. However, these results differ in that no groups by trial blocks interaction was found. That is, at the end of the acquisition phase there remained a marked decrement to performance accuracy for both the random and serial groups.

<u>Retention Phase</u>

The analyses involved 3 (groups) X 3 (trial block 6 plus the two retention trial blocks) X 3 (movement patterns) models with repeated measures on the last two factors. The ANOVA on E revealed a main effect for trial blocks, $\underline{F}$ (2, 54) = 2.32, ω^2 = 1.9%, as well as a groups by blocks interaction, $\underline{F}$ (4, 54) = 6.38, ω^2 = 8.6%. The MANOVA for |CE| and VE also revealed these effects for blocks, $\underline{F}$ (4, 106) = 4.57 and for the groups by blocks interaction, $\underline{F}$ (8, 106) = 3.08. Follow-up ANOVAs revealed significant differences on the blocks effect, $\underline{F}$ (2, 54) = 6.43, ω^2 = 4.3% and the interaction, $\underline{F}$ (4, 54) = 6.12, ω^2 = 8.1% for |CE| but not for VE. Post-hoc analyses revealed that for the blocked group, the retention trial blocks were performed significantly poorer than the last block of acquisition trials. However, for both the serial and random groups, there were no differences between these trial blocks. Further, the random group was significantly more accurate than the blocked group on the second set of retention trials. No significant differences were observed between the serial group and the other two groups (see Figure 5).

In addition, a group by movement pattern interaction was also significant for E, $\underline{F}$ (4, 54) = 2.88, ω^2 = 2.0%. The Newman-Keuls test however, failed to detect any differences among the means.

The results of the present experiment are very enlightening from several aspects. Orienting the goals of the task to invoke more problem-solving activities involved in processing KR produced dramatic effects on acquisition performance. In fact, the difference between the random/serial and blocked groups, which eventually vanished in the previous studies, was maintained throughout the entire acquisition phase. Following Acquisition, the blocked group's performance rapidly declined over the period of no-KR trials whereas both the random and serial groups actually improved their performance somewhat (see Figure 5). These data both support the previous findings of detrimental/ facilitory effects regarding practice schedules and extend the theoretical implications to include tasks which tend to evoke more problem-solving operations.

The retention advantage of random over blocked groups, while not as robust as was found in Experiments 1 and 2, nevertheless supports the theoretical notion of event repetition effects. While the locus of contextual variety on acquisition performance as an effect produced by event repetitions supports the findings from Experiment 2 very well, the lack of a significant advantage of serial over blocked practice schedules during retention offers a slightly different perspective. That is, the nature of the serial group, while sufficient to produce sizeable effects under conditions where KR has limited meaningfulness for a subject (as in Experiments 1 and 2), fails to maximize the potential benefits of non-repetition trials in "problem solving" motor tasks. One hypothesis for this finding is that the nature of the serial practice schedule prevents direct testing of some movement timing hypotheses that might be generated by the subject. For example, under conditions where a subject serially practiced movement patterns in the order (of criterion times) 900-1200-1050-900..., he/she would never be able to use KR from the 900 msec pattern immediately in developing a strategy for performing the 1050 msec pattern since the 1200 msec pattern was always performed next. This situation also occurs for the pairs 1200-900 and 1050-1200 in the above example sequence. For the random group however, all possible permutations occur many times during the acquisition phase. That this benefit exerts itself (albeit to minor extents) during retention underscores the importance of repetition of events in direct temporal contiguity with all other possible events, especially when KR is very important in achieving the goals of the task. That is, given a current motor problem is not a repetition of the previous trial, learning will be facilitated if the processing activities do not always follow, or further, do not always depend upon the KR from the same preceeding event.

A consideration of the descriptive error measures (|CE| and VE) in the present experiment also reflect interesting changes. Consonant with the notion that |CE| reflects a response bias averaged across a group of individuals and that VE denotes response consistency (e.g., Schutz, 1977), the practice schedule effects seem to be exerted differently at acquisition and retention. Over the entire acquisition phase, subjects in the random and serial groups had larger accuracy biases and inconsistencies than did the blocked group. However, during retention the only significant effect between conditions was attributable to the large increase in the blocked group's response bias. Indeed, an examination of the constant error scores across all retention trials reveals that 9 of the 10 subjects in the blocked group had positively biased timing errors (overall group mean CE = +75 msec). This consistent shift towards slower performance scores during KR-withdrawal trials was not observed for the other groups though. Under the random acquisition conditions, 6 subjects revealed positive error shifts ($\underline{M}$ = +24) and 4 subjects had negative response biases ($\underline{M}$ = -23) across the no-KR trials. For the serial group, 4 subjects were positively biased ($\underline{M}$ = +37) and 6 subjects underestimated the criterion times (*M* = -37). These CE data suggest then, that learning under blocked acquisition conditions is not only detrimental to later retention accuracy, but also that this inaccuracy is due to a shift towards overestimating the learned criterion times.

For VE, no differences between the practice schedule manipulations were observed. This suggests that although the blocked group produced much greater biases in timing judgement following the removal of KR, their ability to produce what they believed to have been accurate judgements was quite consistent.

General Discussion

The present series of experiments provides evidence which seems to clearly point to the cognitive activity which occurs between repetitions of the same movement pattern as the locus of the contextual variety effect. For blocked conditions, the subsequent practice on a particular movement pattern occurs in the absence of any intervening events which require cognitive activity. Thus the action plans for a subsequent movement may be devised and tested, based upon experience from the previous trial, well before the following trial. However, under random and serial conditions, the action plans cannot be immediately devised and tested, since action plans for intervening trials requiring movement plans must first be generated. When a subsequent repetition is eventually tested, the experience from the preceeding trial for that particular pattern is no longer as informative, due to the intervening cognitive and motor activities. Subsequently, subjects must undertake more extensive problem-solving activities to generate a plan of action. That acquisition performance might be facilitated under event repetition (i.e., blocked) conditions is consonant with the literature on repetition effects for more simplified responses (see Kirby, 1980 for a review). However, that this type of practice is <u>detrimental</u> to retention (relative to random and serial conditions) has no precedent in the motor behavior literature.

The results of Experiment 3 are particularly interesting given Schmidt's recent reevaluations of the role of KR in skill acquisition (Schmidt, 1982, Chapter 13). He argued that under conditions where the processing of error information is impeded (as in the trials-delay studies and under low relative-KR conditions), subjects are forced to find less efficient, task-relevant cues to improve performance. Conversely, when it is readily available to solve motor problems, KR acts to <u>guide</u> performance, serving as a "crutch" upon which performance may be facilitated. When KR is later removed, Schmidt noted that these conditions where KR earlier served to guide performance produced large performance decrements relative to the cases where KR was not available to be used as a crutch.

Indeed, the paradox noted by Schmidt is quite similar to the contextual variety effects as produced in Experiment 3. That is, event repetitions (blocked practice trials) promote the immediate utilization of KR, serving to guide performance yet detrimental to no-KR retention trials. However, under conditions where KR cannot be used immediately to solve motor problems (under random and serial practice schedules), the cognitive problem-solving activities involve more of the task-relevant information as gathered from the performance of non-repetitive, but related, events.

While the results from Experiment 3 seem to fit Schmidt's arguments well, the findings from Experiment 1 and 2 cannot be so directly subsumed under this KR rationale. Moreover, the evidence from these experiments seem to point to a more general phenomenon of cognitive-motor functioning during skill acquisition, of which the KR paradoxes noted by Schmidt and the contextual variety effect demonstrated herein are simply paradigms which produce this phenomenon. In the case of the KR-related studies noted by Schmidt and the KR-contextual variety study reported here (Exeriment 3), by making the direct utilization of error feedback more difficult {e.g., by delaying KR (trials-delay technique) or under random or serial practice schedules}, there is a performance decrement during acquisition trials but a facilitation of retention under KR-withdrawn trials. A similar result also occurs under contextual variety conditions when remembering the actions is the relevant cognitive activity. The common elements among all of these findings though, is the manner by which these experimental manipulations force subjects to adopt strategies in the attempt to improve performance (cf. Singer & Pease, 1976). In all cases an emphasis is placed upon the performer to adopt more <u>cognitively effortful</u> problem-solving activities. In the KR-related cases, the increased effortful processing invokes an enheightened use of task-relevant features and sensory feedback to augment the interference involved in utilizing KR (Schmidt, 1982). In the contextual variety situations present in Experiments 1 and 2 and elsewhere (Shea & Morgan, 1979; Del Rey et al., in press), the increase in effortful processing due to random and serial practice schedules is manifested because subjects passively <u>remember</u> the action plans prior to movement (in the case of repetitive events), but instead must <u>actively regenerate</u> a new movement plan on each trial during the acquisition phase in the case of non-repetitive events. Indeed, this effort-related explanation to the above phenomenon is consonant with recent perspectives on the acquisition of purely cognitive tasks (Eysenck & Eysenck, 1979; Kunen, Green & Waterman, 1979; Tyler, Hertel, McCallum & Ellis, 1979) as well as short-term retention of preselected movements (e.g., Kelso, 1981; Lee & Gallagher, 1981).

This theoretical perspective may be seen as an extension of the theories of Fitts (1964) and Adams (1971) in that not only is the emphasis placed upon cognitive-motor activities during the initial phase of skill acquisition but also the effort with which these processing activities are undertaken. Given this perspective, the current challenge is to determine not only how these cognitive-motor interactions occur but also what conditions facilitate the effort by which these interactions are undertaken.

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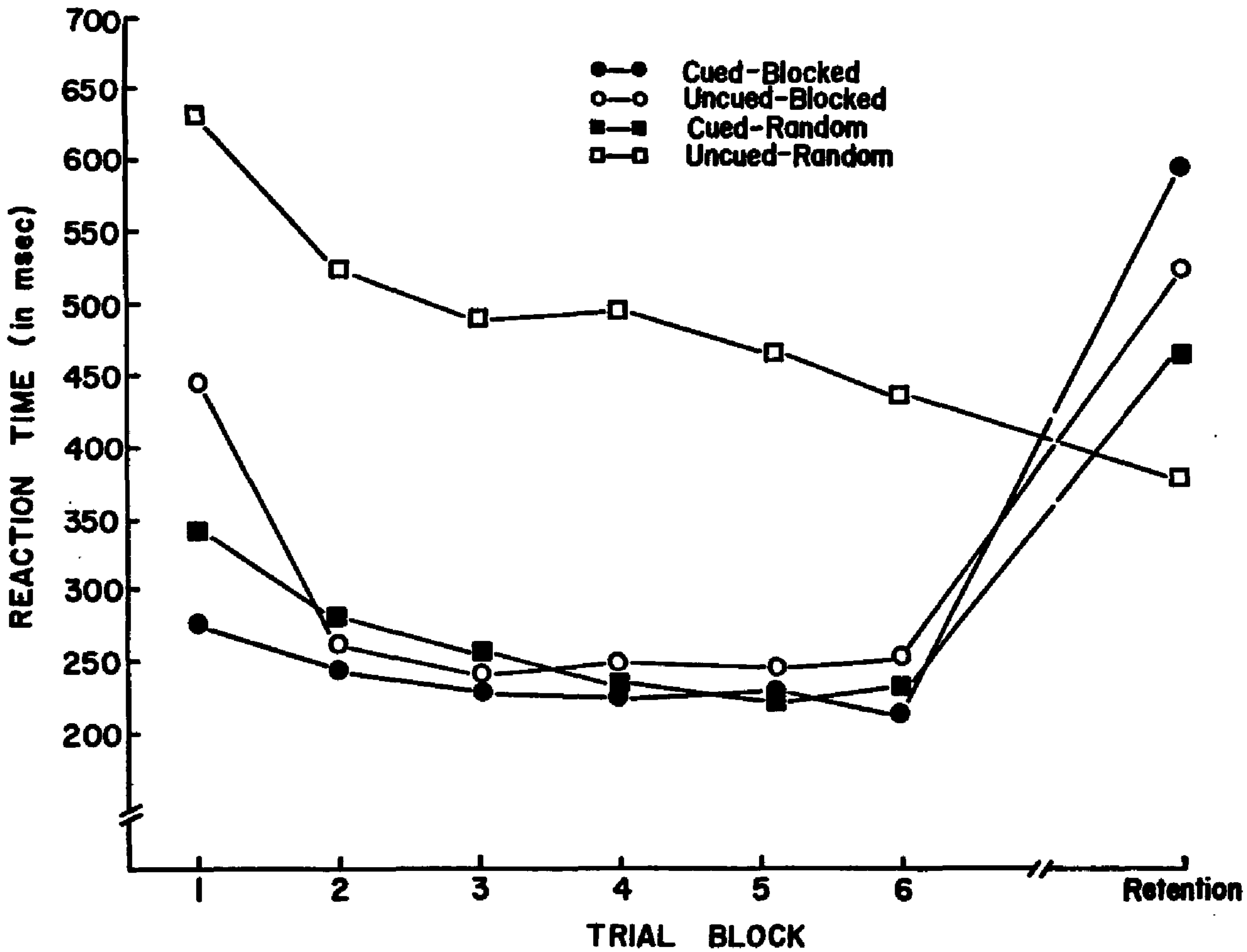
Footnotes

1. In a related study (Del Rey, Wughalter & Whitehurst, in press) contextual variety effects were produced using a task which involved coincidence anticipation and as such does not suffer exactly the same problems of choice vs. simple responses as does the Shea and Morgan study. Nevertheless, the problem is still apparent because the subjects in the random condition did not know prior to the beginning of apparent motion which of three learning speeds was being tested while subjects in the blocked group were cognizant at all times.
2. It should be noted that the uncued-blocked vs. cued-blocked comparison is <u>not</u> an assessment of response paradigm holding contextual variety constant because on only three trials (the start of each new block of trials) is the task a choice response. On all other trials, the very nature of the blocked group reduces the task to a simple response paradigm.
3. An examination of the task procedures as well as subjects' verbal reports indicated that the "red" pattern facilitated RT and MT regardless of other experimental variables (although the ω^2s were generally small). This could be due to the fact that the red signal to respond light, which was located on the right side of the rear panel, was associated with

the only response whose initial movement was to a barrier on the right. Thus, the mnemonic "R" could be developed to associate the red light, its right spatial location and the right initial movement direction. That is, the response for this pattern was more readily retrievable for action. Recalling that Battig (1979) promoted increased similarity among items to be learned as a factor contributing to contextual interference (in addition to contextual variety), this mnemonic suggests that the production of a cognitive action strategy might be one way in which the constraints of contextual interference might be overcome (cf. Wughalter, 1981).

Figure Captions

1. Group RT performance across acquisition and retention phases for Experiment 1.
2. Group MT performance across acquisition and retention phases for Experiment 1.
3. Group RT performance across acquisition and retention phases for Experiment 2.
4. Group MT performance across acquisition and retention phases for Experiment 2.
5. Group absolute constant error performance across acquisition and retention phases for Experiment 3.


Cued-Blocked
Uncued-Blocked
Cued-Random
Uncued-Random
REACTION TIME (in msec)
700
650
600
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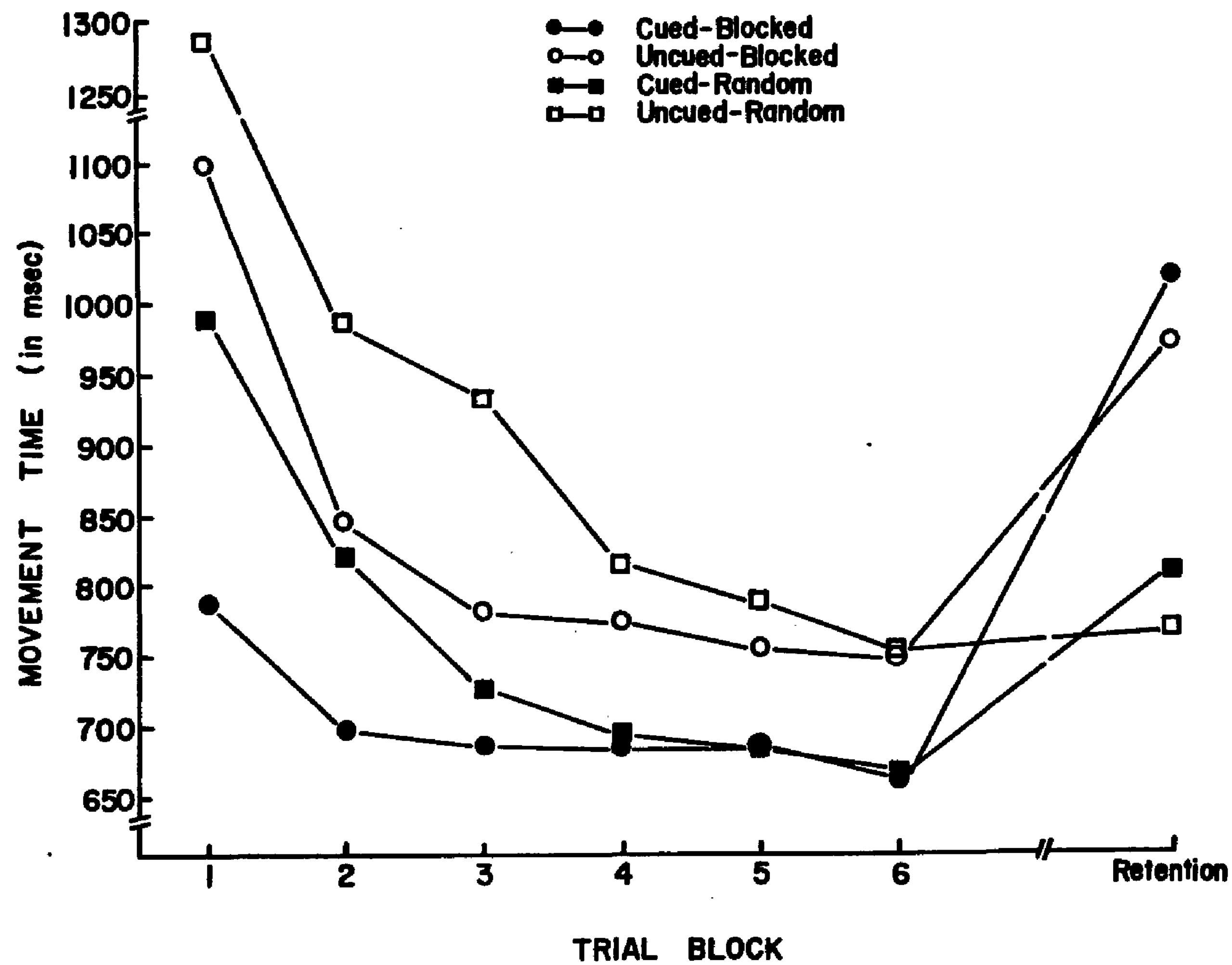
500
450
400
350
300
250
200
1
2
3
4
5
6
Retention
TRIAL BLOCK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Cued-Random
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1300
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750
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MOVEMENT TIME (in msec)
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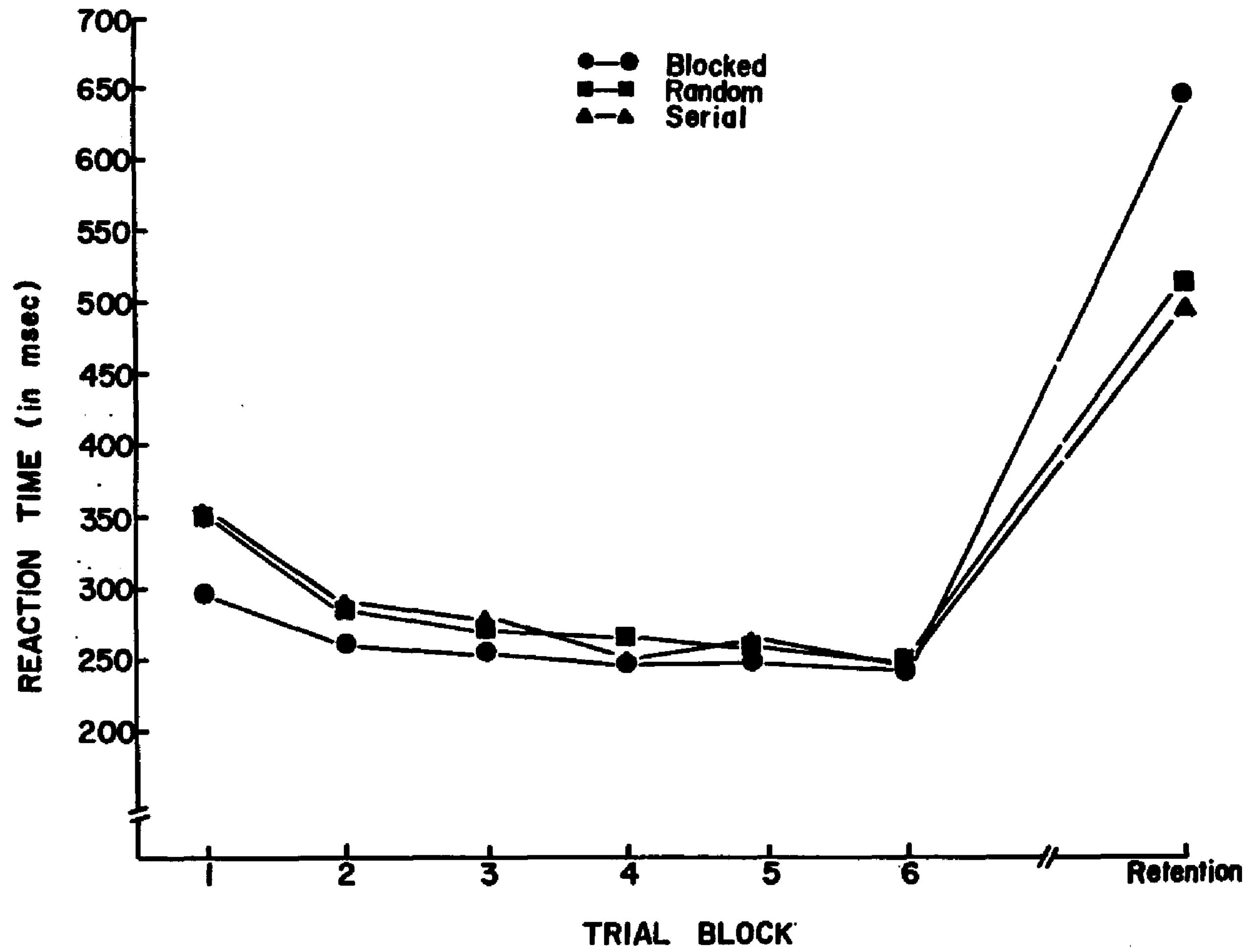
6
Retention
TRIAL BLOCK


Blocked
Random
Serial
REACTION TIME (in msec)
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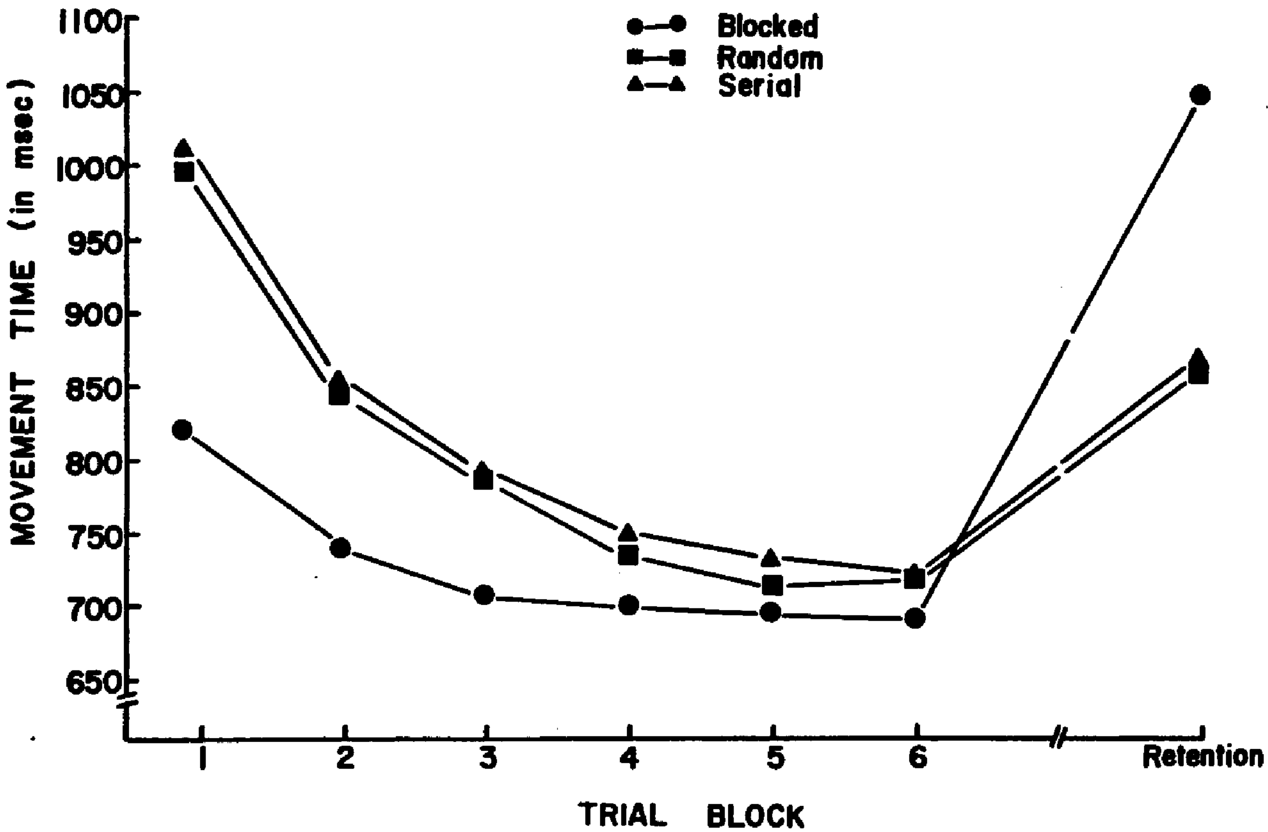
Retention
TRIAL BLOCK



Blocked
Random
Serial
MOVEMENT TIME (in msec)
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1050
1000
950
900
850
800
750
700
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1
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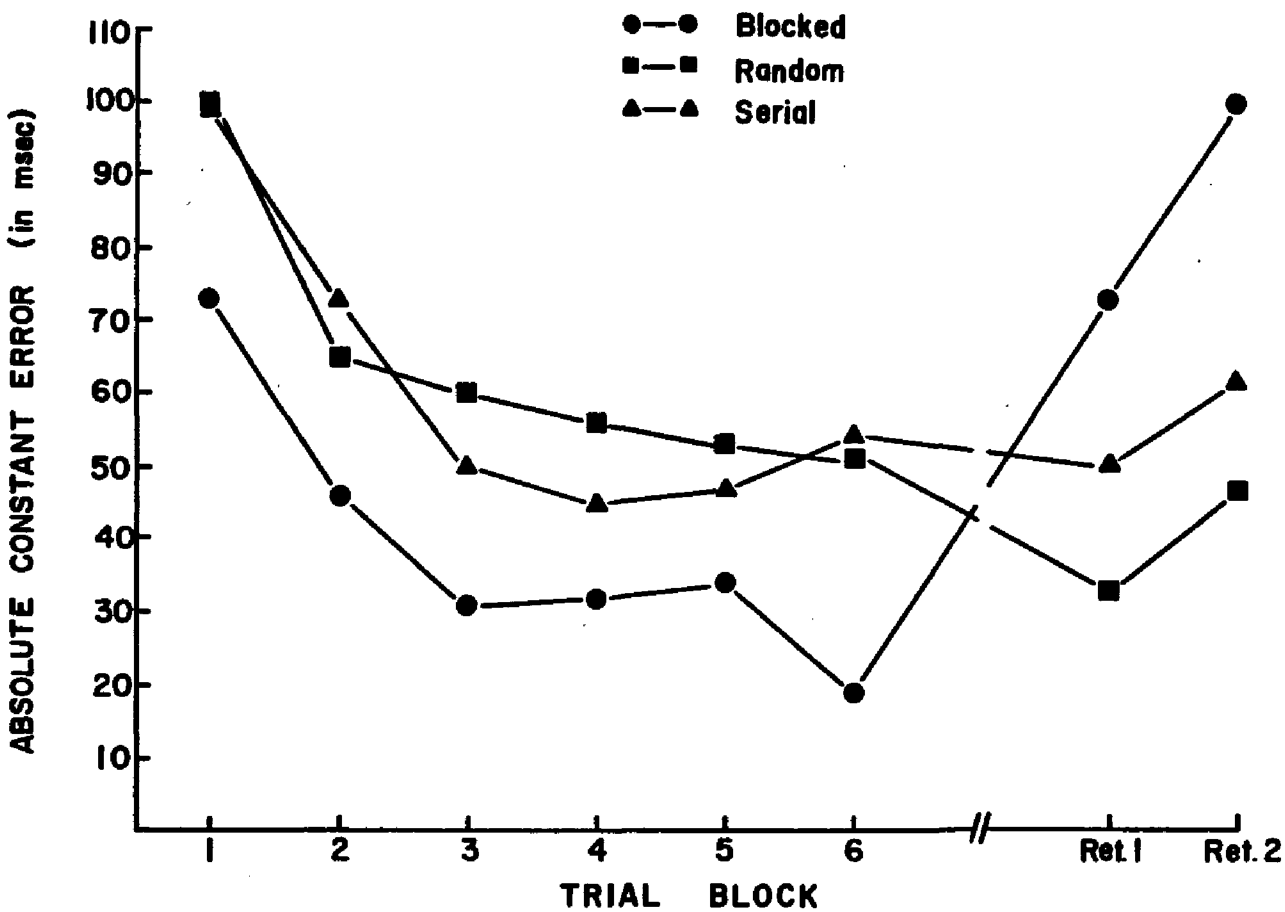
6
Retention
TRIAL BLOCK


Blocked
Random
Serial
ABSOLUTE CONSTANT ERROR (in msec)
110
100
90
80
70
60
50
40
30
20
10
1
2
3
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Ret. 1
Ret. 2
TRIAL BLOCK

APPENDICES

APPENDIX A

Contextual Interference: Some Background Issues and Future Directions

Contextual Interference: Some Background Issues and Future Directions

Interference is a term which has been used throughout the psychological literature to denote a factor which negatively affects the learning of word lists (e.g., Kintsch, 1977) and motor skill (e.g., Stelmach, 1974). However, the late William Battig suggested that this negative influence while easily demonstrable for acquisition performance, is not maintained for tests of retention and transfer in verbal tasks. Moreover, interference during acquisition was suggested to *facilitate* retention and transfer (Battig, 1966, 1972). The purpose of the present discussion is twofold: a) to sketch the progression of Battig's theory from the original notion of "intratask interference" to the present conceptualization of "contextual interference", and b) to offer suggestions regarding future research directions of Battig's conceptualizations to applications in the motor domain. (For a more complete history of the topic one should read Battig's original theoretical articles -- Battig, 1966, 1972, 1979).

Initial support for Battig's contentions were obtained under two paradigms of word list learning, paired-associate and serial learning. For paired-associate procedures, support (i.e., a decrement to acquisition performance followed by a facilitated delayed retention) was obtained under the following conditions: a) by increasing the acoustic, formal and|or associative similarity of words within a list, b) for double-function as opposed to single-function word lists, c) for longer lists, d) for bidirectional as opposed to unidirectional lists, and e) for spaced practice conditions. Using a serial learning paradigm, support was found when: a) incompatible numerical cues were added to the word list, and b) when the starting positions were different on each trial. To Battig (1972), these instances revealed a significant relationship _between the list items themselves_, making the lists more difficult to remember during acquisition of the task. Since the locus of the effect was clearly placed upon the task itself, Battig conceived that the effect demonstrated "intratask interference".

Additional support for Battig's contention extended the locus of the interference arising from within the task to factors, extraneous to the task, which induce a subject to undertake additional processing activities to acquire the task. One such factor was demonstrated by Nitsch (cited in Bransford, Franks, Morris & Stein, 1979), who found in a concept attainment task, that subjects presented similar examples of a concept on consecutive trials readily attain the concept but show poor understanding (as assessed by a transfer to novel examples of the concept). However, subjects shown varied examples revealed the opposite: slow attainment yet good understanding of the concept. These findings were argued that dissimilar examples forced subjects to process the concept in a variety of contexts. That transfer was facilitated in this latter group illustrates a prime example of overcoming the constraints upon memory which suggest that remembering is optimized only when the original encoding context is available during retrieval (Tulving & Thomson, 1973). Battig (1979) saw this as quite similar to the effect produced by intratask interference. Furthermore, Battig cited other lines of evidence, published since his original two articles, which clearly focused the functional locus of interference upon the subjects' processing activities. Thus, he replaced the label "intratask" with "contextual" to denote

> a broader and less direct conceptualization of functional interference including not only the interfering aspects of the task and materials but also factors extraneous to the task and inferred interference-related processing activities ... One major consequence of such an expanded view of contextual interference is to tie closely to changes across trials in the experimental and processing contexts as potential covariates if not determinants of contextual interference (Battig, 1979, p. 34).

In his revamped theory, Battig viewed contextual interference effects as arising from manipulations of intralist factors and|or the contextual conditions subserving acquisition.

Recent investigations by Shea and his colleagues as well as the present series of studies have provided considerable evidence that contextual variety conditions (such as those produced by blocked, random and serial practice schedules) is a major contributor to contextual interference effects in motor skill acquisition (Shea & Zimny, in press; Battig & Shea, 1980). Nevertheless, a number of other, recent investigations provide evidence consonant with Battig's theme.

Given a similar set of movement tasks to be learned, Wughalter (1981) found that providing a mnemonic to facilitate retrieval of an action plan helped to overcome intratask interference. Similarly, in Experiment 1 reported here, subjects were able to develop a mnemonic "R" to associate the far right signal to respond, the red signal-pattern pair, and the only movement pattern which began to the right. Similar to Wughalter's finding, the influence of intratask similarity during retention was overcome. That is, the random group performed faster than the blocked group during retention for the "green" and "blue" patterns only. While these data implicate the influences of between-pattern similarity on contextual interference effects, a direct test has not yet been conducted. However, an experiment to assess this notion could easily be devised, utilizing the

Shea-Morgan task. That is, a rating scale of similar features shared between three patterns for instance, could be devised based upon the number of shared features of each task. Given the following designation (1=left front barrier; 2=right front; 3=left-center; 4=right-center; 5=left-rear; 6=right-rear), the patterns 1-2-5, 1-4-3, and 2-4-5 each would share one common barrier to be knocked over at a particular point during the three-barrier sequence with another pattern, for a total of three shared between-pattern features. Similarly, the patterns 1-2-5, 1-4-3, and 2-3-5 would have two shared features. Accordingly, the triplets 1-2-5, 1-4-3, 2-3-6 and 1-2-5, 3-4-6, 2-3-4 would share 1 and 0 common barriers at any particular point during the knock-down sequence, respectively. From Battig's theory, the predicted outcome would be that as the similarity between patterns increased (i.e., more shared barriers), acquisition performance would show a decrement yet retention should be facilitated.

Factors more akin to what Battig denoted as extraneous to intratask manipulations have also been shown to contribute to contextual interference effects in motor skill acquisition. Del Rey, Wughalter and Whitehurst (in press) have recently shown that contextual variety effects (blocked vs random practice) may be attenuated when the experience of the subject is considered. While their study revealed similar findings to Shea and Morgan's (1979) study for novice subjects, they found no benefit of random over blocked conditions during retention in a coincidence anticipation task when the subjects were all experienced athletes in a sport which demanded predictive judgements. Indeed, similar interactions between activity levels in older females and interference effects have also been found (Del Rey, in review). Thus, it seems that the "knowledge base" which a subject brings into an experimental session has a profound influence upon interference effects.

Experiment 3 from the present series reveals another interesting aspect of the "context" issue as produced under random vs. serial presentation conditions. While these two groups performed identically under speeded conditions (Experiment 2), the retention findings for the random group in Experiment 3 was markedly better (though not significant) than the serial group. A plausible cause for this discrepancy is found in the information received for one pattern and utilized in forming a strategy for an upcoming movement plan. Since the order of practice trials was constant throughout acquisition in the serial group, the experience (i.e., error information) gained from performing one particular pattern could be used in devising a strategy for only <u>one</u> other pattern on an immediately succeeding trial. In other words, performing a particular movement pattern would always be constrained within the context of the same immediately preceeding pattern and the same immediately succeeding pattern. On the other hand, a random pratice schedule induces performance on a particular pattern within the context of many possible preceeding and succeeding patterns throughout the acquisition phase.

A better test of the above notion would be to restructure the random condition, focusing on one particular pattern, and devising variability of context in a controlled manner. For example, in the sequence BBGRBRGGBRGR the "Blue" pattern is performed in the context of all possible succeeding patterns (i.e., "red", "green" and itself). In the sequence RBGGRBBRBGGR the "blue" pattern is never performed following the "green" pattern. Whereas in the serial pattern RBGRBGRBGRBG the "blue" pattern is never performed following itself or the "green" pattern. A comparison of the retention differences for the "blue" pattern would provide insight into the idea of <u>context</u> variability as it contributes to contextual interference effects.

ADDITIONAL REFERENCES

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APPENDIX B

Illustration of Apparatus

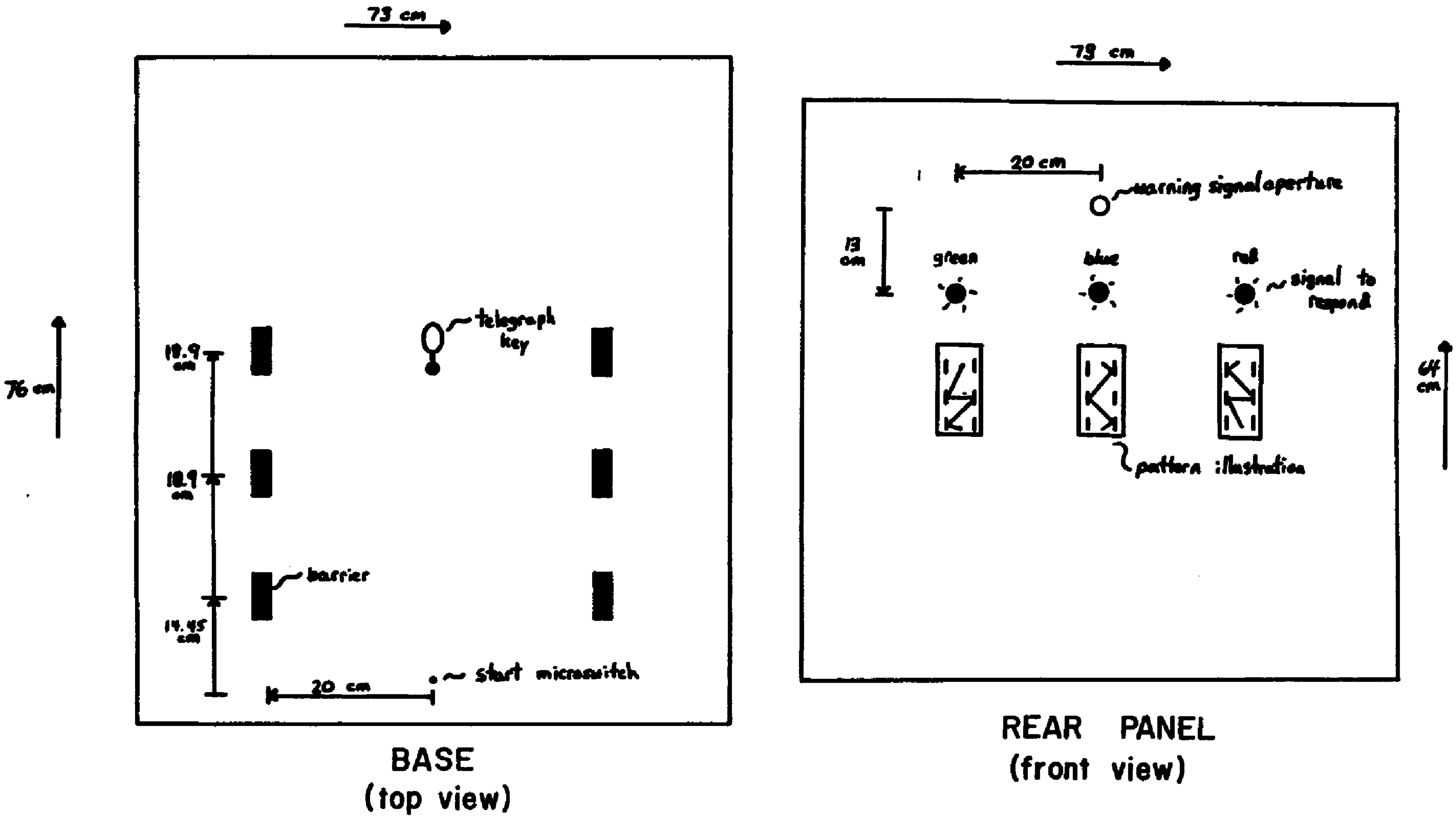

Figure 6. Illustration of barrier knock-down apparatus.

APPENDIX C

MANOVA and ANOVA Tables

TABLE 1

MANOVA for Experiment 1 Data on RT and MT

Source	Acquisition	Retention
Cue	F(2,19) = 18.27	F(2,19) = 0.17
Order	F(2,19) = 11.45	F(2,19) = 1.66
C×O	F(2,19) = 6.61	F(2,19) = 0.49
Block	F(10,198) = 37.21	F(2,19) = 26.72
C×B	F(10,198) = 7.45	F(2,19) = 5.29
O×B	F(10,198) = 5.21	F(2,19) = 8.83
C×O×B	F(10,198) = 1.06	F(2,19) = 1.53
Pattern	F(4,78) = 7.76	F(4,78) = 10.85
C×P	F(4,78) = 2.35	F(4,78) = 0.72
O×P	F(4,78) = 0.72	F(4,78) = 2.75
C×O×P	F(4,78) = 0.52	F(4,78) = 0.56
B×P	F(20,398) = 1.97	F(4,78) = 6.23
C×B×P	F(20,398) = 0.82	F(4,78) = 2.12
O×B×P	F(20,398) = 0.48	F(4,78) = 3.36
C×O×B×P	F(20,398) = 0.32	F(4,78) = 0.31

TABLE 2

RT ANOVA for Experiment 1 Acquisition Data

Source	df	SS	F
Cue	1	2297458.37	30.64
Order	1	1675272.23	22.34
C×O	1	1043513.48	13.92
ID(C×O)	20	1499837.68	
Block	5	936911.07	27.97
C×B	5	157285.26	4.69
O×B	5	27271.29	0.81
C×O×B	5	46548.93	1.39
ID×B(C×O)	100	670028.09	
Pattern	2	67222.33	5.56
C×P	2	40333.97	3.34
O×P	2	5275.08	0.44
C×O×P	2	1448.83	0.12
ID×P(C×O)	40	241831.75	
B×P	10	38354.35	1.30
C×B×P	10	27032.38	0.92
O×B×P	10	10022.71	0.34
C×O×B×P	10	10686.07	0.36
ID×B×P(C×O)	200	588922.46	

TABLE 3

MT ANOVA for Experiment 1 Acquisition Data

Source	df	SS	F
Cue	1	2374816.89	10.52
Order	1	665052.08	2.95
C×O	1	23585.33	0.10
ID(C×O)	20	4514287.64	
Block	5	5477357.90	117.14
C×B	5	605628.21	12.95
O×B	5	510197.97	10.91
C×O×B	5	37454.66	0.80
ID×B(C×O)	100	935147.57	
Pattern	2	876706.47	18.09
C×P	2	142017.25	2.93
O×P	2	44148.37	0.91
C×O×P	2	33558.87	0.69
ID×P(C×O)	40	969381.35	
B×P	10	188493.99	2.65
C×B×P	10	62594.88	0.88
O×B×P	10	42219.65	0.59
C×O×B×P	10	18645.04	0.26
ID×B×P(C×O)	200	1420191.42	

TABLE 4

RT ANOVA for Experiment 1 Retention Data

Source	df	SS	F
Cue	1	16813.44	0.31
Order	1	12432.25	0.23
C×O	1	49284.00	0.92
ID(C×O)	20	1075474.72	
Block	1	1522756.00	47.22
C×B	1	353430.25	10.96
O×B	1	518880.11	16.09
C×O×B	1	70490.25	2.19
ID×B(C×O)	20	645004.05	
Pattern	2	218277.04	16.51
C×P	2	11758.93	0.89
O×P	2	71075.04	5.38
C×O×P	2	9640.54	0.73
ID×P(C×O)	40	264427.77	
B×P	2	173277.79	9.59
C×B×P	2	41152.79	2.28
O×B×P	2	59817.51	3.31
C×O×B×P	2	9788.79	0.54
ID×B×P(C×O)	40	361242.44	

TABLE 5

MT ANOVA for Experiment 1 Retention Data

Source	df	SS	F
Cue	1	15876.00	0.14
Order	1	379045.44	3.46
C×O	1	14.69	0.00
ID(C×O)	20	2191336.61	
Block	1	1266375.11	38.36
C×B	1	147328.02	4.46
O×B	1	396690.02	12.02
C×O×B	1	196.00	0.01
ID×B(C×O)	20	660239.83	
Pattern	2	429980.54	12.79
C×P	2	18524.04	0.55
O×P	2	27534.43	0.82
C×O×P	2	13383.43	0.40
ID×P(C×O)	40	672561.55	
B×P	2	123710.51	4.19
C×B×P	2	59470.18	2.02
O×B×P	2	105808.18	3.59
C×O×B×P	2	3306.12	0.11
ID×B×P(C×O)	40	590153.00	

TABLE 6

MANOVA for Experiment 2 Data on RT and MT

Source	Acquisition	Retention
Group	$F(4,52) = 0.71$	$F(4,52) = 1.44$
Block	$F(10,268) = 36.54$	$F(2,26) = 139.13$
G×B	$F(20,268) = 2.86$	$F(4,52) = 6.99$
Pattern	$F(4,106) = 14.77$	$F(4,106) = 7.63$
G×P	$F(8,106) = 1.77$	$F(8,106) = 0.50$
B×G	$F(20,538) = 0.42$	$F(4,106) = 0.94$
G×B×P	$F(40,538) = 0.98$	$F(8,106) = 0.85$

TABLE 7

RT ANOVA for Experiment 2 Acquisition Data

Source	df	SS	F
Group	2	49247.74	0.95
ID(G)	27	701737.08	
Block	5	441532.49	37.41
G×B	10	34593.60	1.47
ID×B(G)	135	318707.61	
Pattern	2	4991.04	1.04
G×P	4	23658.67	2.46
ID×P(G)	54	130005.49	
B×G	10	6017.37	0.50
G×B×P	20	24941.77	1.03
ID×B×P(G)	270	327670.3	

TABLE 8

MT ANOVA for Experiment 2 Acquisition Data

Source	df	SS	F
Group	2	736999.65	1.28
ID(G)	27	7775987.50	
Block	5	3573840.89	105.49
G×B	10	385740.67	5.69
ID×B(G)	135	914761.59	
Pattern	2	513732.90	28.57
G×P	4	49894.45	1.39
ID×P(G)	54	485427.64	
B×P	10	9986.56	0.31
G×B×P	20	68055.81	1.07
ID×B×P(G)	270	856317.95	

TABLE 9

RT ANOVA for Experiment 2 Retention Data

Source	df	SS	F
Group	2	179462.07	2.91
ID(G)	27	833391.81	
Block	1	41777894.04	169.05
G×B	2	211421.70	4.28
ID×B(G)	27	667265.75	
Pattern	2	1467.41	0.13
G×P	4	19705.85	0.87
ID×P(G)	54	307267.73	
B×P	2	129.03	0.01
G×B×P	4	34847.36	1.45
ID×B×P(G)	54	324274.60	

TABLE 10

MT ANOVA for Experiment 2 Retention Data

Source	df	SS	F
Group	2	256742.57	0.95
ID(G)	27	3633772.66	
Block	1	2073680.00	141.53
G×B	2	444271.60	15.16
ID×B(G)	27	395610.73	
Pattern	2	359951.87	16.49
G×P	4	14081.15	0.32
ID×P(G)	54	589225.63	
B×P	2	36400.83	1.84
G×B×P	4	24081.86	0.61
ID×B×P(G)	54	535523.96	

TABLE 11

MANOVA for Experiment 3 Data on E and /CE/

Source	Acquisition	Retention
Group	F(4,52) = 5.21	F(4,52) = 1.72
Block	F(10,268) = 8.62	F(4,106) = 4.57
G*B	F(20, 268) = 0.79	F(8,106) = 3.08
Pattern	F(4,106) = 2.41	F(4,106) = 2.25
G*P	F(8,106) = 1.23	F(8,106) = 1.86
B*P	F(20,538) = 1.10	F(8,214) = 0.88
G*B*P	F(40,538) = 0.98	F(16,214) = 1.22

TABLE 12

E ANOVA for Experiment 3 Acquisition Data

Source	df	SS	F
Group	2	76644.35	6.55
ID)G)	27	157989.69	
Block	5	267494.24	20.81
G*B	10	27046.46	1.05
ID*B(G)	135	346999.87	
Pattern	2	14664.62	2.48
G*P	4	15117.11	1.28
ID*P(G)	54	159523.28	
B*P	10	31156.21	1.49
G*B*P	20	44517.45	1.07
ID*B*P(G)	270	563823.12	

TABLE 13

/CE/ ANOVA for Experiment 3 Acquisition Data

Source	df	SS	F
Group	2	66965.03	12.56
ID(G)	27	71951.03	
Block	5	159725.84	14.10
G*B	10	8460.58	0.37
ID*B(G)	135	305878.23	
Pattern	2	15197.54	2.22
G*P	4	14699.72	1.07
ID*P(G)	54	185178.40	
B*P	10	35871.54	1.80
G*B*P	20	31353.65	0.79
ID*B*P(G)	270	537569.13	

TABLE 14

VE ANOVA for Experiment 3 Acquisition Data

Source	df	SS	F
Group	2	17211.63	2.04
ID(G)	27	114134.93	
Block	5	77389.86	11.19
G*B	10	19987.12	1.44
ID*B(G)	135	186803.96	
Pattern	2	7512.13	2.70
G*P	4	8248.43	1.48
ID*P(G)	54	75220.87	
B*P	10	6494.82	0.54
G*B*P	20	29512.27	1.22
ID*B*P(G)	270	326712.12	

TABLE 15

E ANOVA for Experiment 3 Retention Data

Source	df	SS	F
Group	2	15856.03	1.33
ID(G)	27	161473.49	
Block	2	17893.53	3.32
G*B	4	68775.46	6.38
ID*B(G)	54	145430.24	
Pattern	2	102.86	0.03
G*P	4	20765.61	2.88
ID*P(G)	54	97203.28	
B*P	4	7145.12	1.52
G*B*P	8	11710.74	1.25
ID*B*P(G)	108	126631.95	

TABLE 16

/CE/ ANOVA for Experiment 3 Retention Data

Source	df	SS	F
Group	2	18750.58	1.73
ID(G)	27	146460.90	
Block	2	37505.45	6.43
G*B	4	71420.50	6.12
ID*B(G)	54	157555.60	
Pattern	2	2369.60	0.62
G*P	4	23455.88	3.09
ID*P(G)	54	102398.73	
B*P	4	5259.61	0.92
G*B*P	8	17998.16	1.58
ID*B*P(G)	108	153934.66	

TABLE 17

VE ANOVA for Experiment 3 Retention Data

Source	df	SS	F
Group	2	3000.74	0.97
ID(G)	27	41878.31	
Block	2	4360.00	2.47
G*B	4	5128.25	1.45
ID*B(G)	54	47675.95	
Pattern	2	5489.20	4.10
G*P	4	2347.12	0.88
ID*P(G)	54	36133.88	
B*P	4	2135.79	0.79
G*B*P	8	5403.00	1.00
ID*B*P(G)	108	73001.64	

APPENDIX D

Cell Means

TABLE 18

Cell Means for Experiment 1

Cue	Order	Block	Pattern	RT	MT
Cued	Blocked	1	Blue	278	802
Cued	Blocked	1	Green	279	821
Cued	Blocked	1	Red	271	740
Cued	Blocked	2	Blue	239	723
Cued	Blocked	2	Green	257	696
Cued	Blocked	2	Red	240	673
Cued	Blocked	3	Blue	225	733
Cued	Blocked	3	Green	244	672
Cued	Blocked	3	Red	220	662
Cued	Blocked	4	Blue	230	717
Cued	Blocked	4	Green	223	671
Cued	Blocked	4	Red	224	667
Cued	Blocked	5	Blue	234	712
Cued	Blocked	5	Green	235	651
Cued	Blocked	5	Red	223	687
Cued	Blocked	6	Blue	214	677
Cued	Blocked	6	Green	218	646
Cued	Blocked	6	Red	214	660
Cued	Blocked	ret	Blue	685	1061
Cued	Blocked	ret	Green	670	1190
Cued	Blocked	ret	Red	437	809
Cued	Random	1	Blue	346	1061
Cued	Random	1	Green	331	992
Cued	Random	1	Red	346	909
Cued	Random	2	Blue	268	834
Cued	Random	2	Green	308	826
Cued	Random	2	Red	265	798
Cued	Random	3	Blue	258	775
Cued	Random	3	Green	279	740
Cued	Random	3	Red	239	696
Cued	Random	4	Blue	247	746
Cued	Random	4	Green	232	675
Cued	Random	4	Red	221	662
Cued	Random	5	Blue	234	735
Cued	Random	5	Green	230	673
Cued	Random	5	Red	231	642
Cued	Random	6	Blue	252	706
Cued	Random	6	Green	223	664
Cued	Random	6	Red	232	626
Cued	Random	ret	Blue	509	870
Cued	Random	ret	Green	479	840
Cued	Random	ret	Red	406	718
Uncued	Blocked	1	Blue	510	1200
Uncued	Blocked	1	Green	425	1160
Uncued	Blocked	1	Red	400	936
Uncued	Blocked	2	Blue	263	965
Uncued	Blocked	2	Green	282	808

Uncued	Blocked	2	Red	251	769
Uncued	Blocked	3	Blue	253	868
Uncued	Blocked	3	Green	240	739
Uncued	Blocked	3	Red	228	743
Uncued	Blocked	4	Blue	269	864
Uncued	Blocked	4	Green	246	728
Uncued	Blocked	4	Red	246	731
Unuced	Blocked	5	Blue	265	828
Uncued	Blocked	5	Green	255	718
Uncued	Blocked	5	Red	228	716
Uncued	Blocked	6	Blue	277	812
Uncued	Blocked	6	Green	247	725
Uncued	Blocked	6	Red	240	706
Uncued	Blocked	ret	Blue	504	1029
Uncued	Blocked	ret	Green	690	1034
Uncued	Blocked	ret	Red	383	859
Uncued	Random	1	Blue	696	1407
Uncued	Random	1	Green	622	1342
Uncued	Random	1	Red	573	1104
Uncued	Random	2	Blue	529	1051
Uncued	Random	2	Green	535	1006
Uncued	Random	2	Red	507	910
Uncued	Random	3	Blue	503	1005
Uncued	Random	3	Green	481	932
Uncued	Random	3	Red	491	862
Uncued	Random	4	Blue	524	834
Uncued	Random	4	Green	513	885
Uncued	Random	4	Red	455	747
Uncued	Random	5	Blue	534	848
Uncued	Random	5	Green	435	785
Uncued	Random	5	Red	428	729
Uncued	Random	6	Blue	478	797
Uncued	Random	6	Green	417	774
Uncued	Random	6	Red	418	675
Uncued	Random	ret	Blue	393	816
Uncued	Random	ret	Green	403	763
Uncued	Random	ret	Red	344	729

TABLE 19

Cell Means for Experiment 2

Group	Block	Pattern	RT	MT
Blocked	1	Blue	304	819
Blocked	1	Green	315	827
Blocked	1	Red	261	818
Blocked	2	Blue	277	715
Blocked	2	Green	246	734
Blocked	2	Red	249	768
Blocked	3	Blue	272	681
Blocked	3	Green	251	710
Blocked	3	Red	235	733
Blocked	4	Blue	252	669
Blocked	4	Green	238	698
Blocked	4	Red	242	739
Blocked	5	Blue	258	669
Blocked	5	Green	245	688
Blocked	5	Red	234	738
Blocked	6	Blue	245	666
Blocked	6	Green	242	683
Blocked	6	Red	229	732
Blocked	ret	Blue	632	968
Blocked	ret	Green	670	1056
Blocked	ret	Red	619	1122
Random	1	Blue	321	942
Random	1	Green	365	998
Random	1	Red	355	1050
Random	2	Blue	282	784
Random	2	Green	283	845
Random	2	Red	275	895
Random	3	Blue	256	752
Random	3	Green	283	758
Random	3	Red	265	846
Random	4	Blue	258	702
Random	4	Green	271	724
Random	4	Red	259	782
Random	5	Blue	259	671
Random	5	Green	249	697
Random	5	Red	259	779
Random	6	Blue	245	681
Random	6	Green	241	704
Random	6	Red	251	771
Random	ret	Blue	512	803
Random	ret	Green	527	875
Random	ret	Red	491	902
Serial	1	Blue	342	968
Serial	1	Green	342	971
Serial	1	Red	355	1101
Serial	2	Blue	271	832
Serial	2	Green	293	853

Serial	2	Red	283	885
Serial	3	Blue	271	780
Serial	3	Green	273	763
Serial	3	Red	273	833
Serial	4	Blue	246	728
Serial	4	Green	247	733
Serial	4	Red	247	790
Serial	5	Blue	251	728
Serial	5	Green	260	705
Serial	5	Red	257	762
Serial	6	Blue	231	692
Serial	6	Green	261	706
Serial	6	Red	240	760
Serial	ret	Blue	491	797
Serial	ret	Green	455	834
Serial	ret	Red	531	972

TABLE 20

Cell Means for Experiment 3

Group	Block	Pattern	E	/CE/	VE
Blocked	1	Blue	107	85	50
Blocked	1	Green	118	61	91
Blocked	1	Red	113	71	65
Blocked	2	Blue	79	59	37
Blocked	2	Green	73	39	59
Blocked	2	Red	58	38	40
Blocked	3	Blue	53	29	35
Blocked	3	Green	60	24	54
Blocked	3	Red	67	40	51
Blocked	4	Blue	55	32	37
Blocked	4	Green	63	35	43
Blocked	4	Red	70	27	60
Blocked	5	Blue	53	23	46
Blocked	5	Green	74	44	55
Blocked	5	Red	71	36	58
Blocked	6	Blue	43	26	31
Blocked	6	Green	33	14	27
Blocked	6	Red	54	17	49
Blocked	ret1	Blue	121	104	48
Blocked	ret1	Green	91	59	62
Blocked	ret1	Red	80	54	53
Blocked	ret2	Blue	134	122	48
Blocked	ret2	Green	121	111	34
Blocked	ret2	Red	87	67	47
Random	1	Blue	159	117	96
Random	1	Green	110	74	76
Random	1	Red	136	107	69
Random	2	Blue	87	59	54
Random	2	Green	88	53	64
Random	2	Red	107	81	62
Random	3	Blue	72	49	45
Random	3	Green	76	45	53
Random	3	Red	130	86	90
Random	4	Blue	61	35	49
Random	4	Green	95	60	65
Random	4	Red	91	73	52
Random	5	Blue	83	49	56
Random	5	Green	80	57	51
Random	5	Red	81	51	58
Random	6	Blue	77	59	44
Random	6	Green	68	36	52
Random	6	Red	86	56	57
Random	ret1	Blue	57	32	43
Random	ret1	Green	58	31	44
Random	ret1	Red	66	36	40
Random	ret2	Blue	62	40	38
Random	ret2	Green	73	57	38

Random	ret2	Red	65	43	38
Serial	1	Blue	187	142	103
Serial	1	Green	117	70	79
Serial	1	Red	147	85	108
Serial	2	Blue	135	93	85
Serial	2	Green	82	52	58
Serial	2	Red	118	74	78
Serial	3	Blue	118	74	78
Serial	3	Green	70	39	53
Serial	3	Red	85	48	61
Serial	4	Blue	78	62	41
Serial	4	Green	53	32	35
Serial	4	Red	67	40	44
Serial	5	Blue	59	39	35
Serial	5	Green	80	46	58
Serial	5	Red	81	53	58
Serial	6	Blue	71	35	53
Serial	6	Green	90	65	46
Serial	6	Red	93	60	59
Serial	ret1	Blue	57	31	41
Serial	ret1	Green	98	61	65
Serial	ret1	Red	91	56	64
Serial	ret2	Blue	79	70	28
Serial	ret2	Green	83	52	54
Serial	ret2	Red	90	63	56

VITA

On January 22, 1955 in Windsor, Ontario, Canada, Timothy Donald Lee was born. He attended elementary and high school in Harrow, Ontario and following grade 13, enrolled in the Faculty of Human Kinetics at the University of Windsor. Subsequent to receiving his B.H.K. he spent a year of concentrated study in experimental psychology which eventually lead to an M.A. from the Dept. of Psychology at the University of Windsor in 1979.

From 1979 to 1982, Tim was a teaching and research assistant at Louisiana State University while pursuing a Ph.D. in motor behavior with a specialization in learning and control. The Ph.D. degree was awarded in August, 1982. Subsequent to graduation, Tim was an Assistant Professor at McMaster University, Hamilton, Ontario.

EXAMINATION AND THESIS REPORT

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Title of Thesis: On the Locus of Contextual Interference in Motor Skill Acquisition

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Date of Examination:

June 11, 1982